Agroforest Syst (2006) 68:103–111
DOI 10.1007/s10457-006-9001-1

Short-term response of salal (*Gaultheria shallon* Pursh) to commercial harvesting for floral greenery

Wendy Cocksedge · Brian D. Titus

Received: 24 February 2004 / Accepted: 10 March 2006 / Published online: 6 May 2006

Abstract Salal (*Gaultheria shallon* Pursh), which is widely used for floral greenery, is an important non-timber forest product (NTFP) from the coastal forests of the Pacific Northwest of North America. However, there are no known studies on the impacts of commercial salal harvesting on subsequent growth. A study was therefore initiated to quantify the growth of salal 1 year after commercial harvesting, and to compare this with growth of unharvested salal. The amount of biomass removed from shrubs through commercial harvesting (131 g m^{-2}) was the same as the amount of annual growth in adjacent undisturbed plots (135 g m^{-2}). One year later, the amount of regrowth in previously harvested plots (144 g m^{-2}) was greater than the amount of new growth in adjacent undisturbed plots (111 g m^{-2}). As there was little difference in the weight per current stem, the increased biomass after commercial harvesting was attributed to the observed increase in stem number (60 stems m^{-2}) as compared to undisturbed salal (50 stems m^{-2}). Our study does not incorporate either repeated annual harvesting or variable harvesting intensities, both of which have been anecdotally reported to affect levels of re-growth and therefore sustainability.

Keywords *Gaultheria shallon* · Salal · Floral greenery · Non-timber forest product · Pacific Northwest

Introduction

Floral greenery is both harvested and sold around the world. Although some floral species are grown agriculturally (e.g., leatherleaf fern (*Rumohra adiantiformis*)), most species used in the floral greenery industry are harvested from the wild. In North America, these include sword fern (*Polystichum munitum*), *Vaccinium* spp., and galax (*Galax urceolata*). A variety of mosses and lichens are also harvested in North America, and internationally. However, wild harvesting has led to concerns about the sustainability of the use of some species, especially if they are heavily harvested (e.g., xate palm leaves (*Chaemadorea* spp.) in Guatemala; Nations, 1992).

W. Cocksedge (✉)
Department of Biology, University of Victoria, 1700 STN CSC, Victoria, BC, Canada V8W 2Y2
e-mail: Wendy.Cocksedge@RoyalRoads.ca

W. Cocksedge
Present address: The Centre for Non-Timber Resources, Royal Roads University, 2005 Sooke Road, Victoria, BC, Canada V9B 5Y2

B. D. Titus
Canadian Forest Service, Pacific Forestry Centre, Natural Resources Canada, 506 West Burnside Rd., Victoria, BC, Canada V9A 6N2
e-mail: btitus@nrcan.gc.ca

The most important wild-harvested floral greenery species in the Pacific Northwest of North America is *Gaultheria shallon* (Pursh), commonly know as salal. It is an indigenous, evergreen ericaceous shrub (0.5–2.5 m in height) and is distributed primarily along the Pacific coast from southern Alaska to southern California at low elevations from sea level to about 800 m asl (Fraser et al. 1993). It is not found inland in BC east of the Coast Mountains except for a small population on Kootenay Lake, and is not found inland in the state of Washington east of the Cascade Mountains (Fraser et al. 1993; Sabhasri 1961). Salal grows best in humid climates with mild temperatures, and is particularly abundant on Vancouver Island and adjacent coastal areas (Haeussler and Coates 1986; Sabhasri 1961).

Salal is perennial, with dark green, alternate and ovate to oblong leaves that are broad, hardy and glossy (Fig. 1; see also http://www.eflora.bc.ca/ for colour images). The stems are greenish red when young, and become woody after 3–4 years. Salal has sympodial determinate growth (sensu Bell 1993). The apical meristem on each branch aborts at the end of the growing season and thus does not assert apical dominance after the first growing season (sensu Cline 1997) so that each branch reaches its final length in one growing season (Huffman et al. 1994a). Lateral buds tend to be initiated from the second to fifth primordia (Koch 1983), with the third primordium being the most likely to initiate and produce the longest stem of the branch (Sabhasri 1961). The old stem then bends under the weight of new growth and the new stem grows toward the light. The remaining tip of the original stem eventually dies off, resulting in a zig-zag pattern of stem growth in older plants (Huffman et al. 1994a). The age of different parts of stems can therefore be estimated by counting back the stems from the current growth (Huffman et al. 1994a).

Fig. 1 *Gaultheria shallon* (after Hitchcock C.L. and Cronquist A. 1996. Flora of the Pacific Northwest: An Illustrated Manual. University of Washington Press, Seattle and London, 730 pp. Used with permission)

Both the hardiness and the attractiveness of salal, especially its leaf colour, form and distribution and its branching habit, make it a desirable addition to floral arrangements. The morphological features of salal that are valued by the floral industry vary in different environments (Messier and Mitchell 1994), with forest canopy cover and resulting light availability affecting height (Huffman et al. 1994b), density of aerial stems (Huffman et al. 1994a), leaf size and colour (Smith 1991) as well as resource allocation (Messier 1992) and reproduction (Bunnell 1990). Salal is moderately shade tolerant and tends to grow best under partial shade (Bunnell 1990; Messier 1992), a condition that generally produces the most desirable commercial-quality product with long stems (45–76 cm) and suitable shade leaves for the floral industry (i.e., relatively thin, unblemished leaves with consistent green colouring).

Salal began to be picked as floral greenery early in the 20th century, became the primary wild-harvested floral product in BC in the 1950s, and now comprises approximately 70% (Wills and Lipsey 1999) to 90–95% (Ross 1998) of all wild-harvested floral greenery from the BC coast. Europe is the primary export market for salal, although large volumes are also shipped to Japan, distributed across North America or sold directly to local retailers on the Pacific coast (de Geus 1995; Ross 1998; Jones et al. 2002).

An estimated 12,000–15,000 people harvested salal (either full- or part-time) in BC in 1997, and the collective gross revenue for floral greenery (predominantly salal) was CAD$55–60 million (Wills and Lipsey 1999; 1 CAD = 0.72 USD, averaged over 1997; 1 CAD = 0.81 USD = 0.62 EUR in January 2005). By comparison, the value of floral greenery from the Pacific Northwest coast (including Oregon, Washington, and southern BC) was estimated at

USD$106.8 million for 1994 (Blatner and Schlosser 1997; 1 CAD = 0.73 USD, averaged over 1994).

At harvesting, stems that are rarely 1-year-, usually 2-years-, and increasingly up to 3-years-old are picked. This may represent a significant removal of resources from plants, but only one study has quantified removal of salal biomass through commercial harvesting (Frederickson 2000), and no work has yet been done to determine the impact of harvesting on future growth. Severely reduced shoot lengths and sometimes even death of salal plants can be found in some localized areas on Vancouver Island, and has been attributed by harvesters to over-picking. Quantifying the short-term impacts of commercial salal harvesting on subsequent growth is a first step towards developing sustainable harvesting methods and guidelines. To initiate work in this area, a study was established on southern Vancouver Island to (i) compare biomass removals in commercial harvesting (1- to 3-year-old stems + leaves) with annual above-ground biomass increment (current stems + leaves), and (ii) compare annual above-ground biomass increment (current stems + leaves) in the year immediately after commercial harvesting with growth of undisturbed salal.

Materials and methods

Site descriptions and plot layout

Six sites with commercial-quality salal were located in two areas near Victoria, BC (Fig. 2 and Table 1) that had high levels of security and hence salal had not been previously harvested and would be protected from trespass harvesting over the study period. Two sites were established at Rocky Point (48°19′ N; 123°34′ W) and four approximately 30 km away in the Capital Regional District (CRD) Watershed (48°30′ N; 123°37′ W). Both areas had similar canopy cover (70–75%), dominant species in the overstory (Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), with some grand fir (*Abies grandis* (Dougl ex D. Don) Lindl.) at Rocky Point), dominant (salal) and minor understory species (Oregon grape (*Mahonia nervosa* (Pursh) Nutt.) and sword fern (*Polystichum munitum* (Kaulf.) Presl.)), and commercial-quality salal cover and amount. Microtopography was micro-mounded (< 0.3 m high) to moderately mounded (0.3–1 m high and 3–7 m apart).

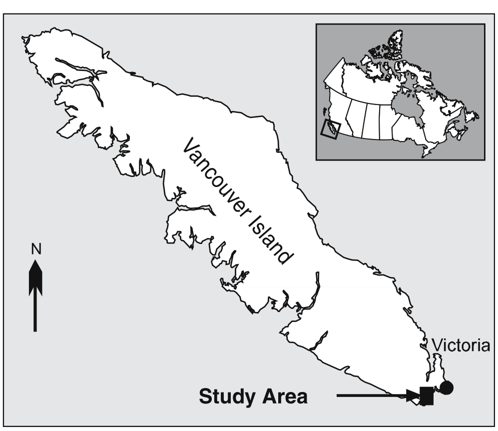

Fig. 2 Location of commercial salal harvesting study area near Victoria, Vancouver Island, BC, Canada

Rocky Point (~9 km^2) is connected to Vancouver Island by a narrow isthmus, and is therefore almost completely bounded by coastal waters. It lies within the Coastal Douglas-fir Moist Maritime (CDFmm) biogeoclimatic subzone (Green and Klinka 1994). The Rocky Point sites had extensive rock outcrops and thin soils, resulting in a relatively open canopy of ~250-year-old overstory trees. The CRD Watershed is ~10 km from the nearest coastal water, and lies within the Coastal Western Hemlock dry maritime (CWHxm1) biogeoclimatic subzone (Green and Klinka 1994). Stands (41- to 60-years-old) had been juvenile thinned and root rot was evident, which resulted in a relatively open canopy. The CRD Watershed sites were at a higher elevation (415–485 m asl) than the Rocky Point sites (55 and 70 m asl). Total precipitation over the 3 years (1998–2000) that affected salal growth over the study period (May 1999–May 2000) was 38% greater at Sooke Lake Dam within the CRD Watershed (1635 mm year^{-1}) than at the weather station (William Head) closest to Rocky Point (1020 mm year^{-1}), with the greatest differences occurring between Oct. and March (data from Meteorological Services Canada, Environment Canada). Monthly average temperatures over winter months were up to 4°C cooler at the Sooke Lake Dam than William Head, although summer precipitation and temperatures were very similar between the two sites. These differences in weather can be attributed to elevation, and to distance from the moderating influence of the coastal waters around Vancouver Island. The sites therefore differ in stand age,

Table 1 Site descriptions for salal harvesting trial

Site variable	Rocky Point No. 1	Rocky Point No. 2	CRD Watershed No. 1	CRD Watershed No. 2	CRD Watershed No. 3	CRD Watershed No. 4
Biogeoclimatic subzone[a]	CDFmm	CDFmm	CWHxm1	CWHxm1	CWHxm1	CWHxm1
Stand age (years)	250+	250+	41–60	41–60	41–60	41–60
Stand height (m)	37.5–46.4	37.5–46.4	19.5–28.4	28.5–37.4	19.5–28.4	19.5–28.4
Site class (quality)	Medium	Medium	Medium	Medium	Medium	Medium
Canopy cover (%)[b]	74	73	75	70	75	72
Site position (macro)[c]	Lower slope	Upper-mid slope	Upper-mid slope	Middle slope	Lower slope	Lower slope
Site position (meso)[c]	Toe	Middle slope	Middle slope	Toe	Level	Middle slope
Site surface shape[c]	Concave	Straight	Convex	Concave	Straight	Concave
Microtopography[c]	Micro-mounded	Micro-mounded	Moderately mounded	Moderately mounded	Slightly mounded	Slightly mounded
Substrate	10% downed wood	15% downed wood	10% downed wood	15% downed wood	5% downed wood	10% downed wood
Slope (%)	5	23	33	22	3	30
Aspect (°)	180	135	40	45	260	330
Elevation (m asl)	55	70	415	430	480	485
Major overstory species[d]	*Pseudotsuga menziesii*, *Abies grandis*	*Pseudotsuga menziesii*, *Abies grandis*, *Tsuga heterophylla*	*Pseudotsuga menziesii*, *Pinus monticola*	*Pseudotsuga menziesii*	*Pseudotsuga menziesii*, *Abies grandis*, *Thuja plicata*	*Pseudotsuga menziesii*, *Tsuga heterophylla*, *Pinus monticola*
Major understory species[d]	*Mahonia nervosa*, *Polystichum munitum*, *Tsuga heterophylla*	*Holodiscus discolor*, *Mahonia nervosa*, *Polystichum munitum*, *Thuja plicata*	*Mahonia nervosa*, *Pteridium aquilinum*, *Thuja plicata*, *Tsuga heterophylla*	*Holodiscus discolor*, *Mahonia nervosa*, *Polystichum munitum*, *Pteridium aquilinum*, *Rosa* spp., *Rubus ursinus*, *Salix* spp., *Thuja plicata*	*Mahonia nervosa*, *Pteridium aquilinum*, *Tsuga heterophylla*	*Alnus rubra*, *Mahonia nervosa*, *Polystichum munitum*, *Prunus emarginata*, *Pteridium aquilinum*, *Rosa* spp., *Rubus ursinus*, *Thuja plicata*

[a] Green and Klinka (1994)

[b] Concave hemispherical densiometer (Forest Densiometers, Bartlesville, OK); readings taken in four cardinal directions (0°, 90°, 180°, 270°) in centre of plot and at each corner

[c] Luttmerding et al. (1990)

[d] *Abies grandis* (Dougl ex D. Don) Lindl.), *Alnus rubra* (Bong.), *Holodiscus discolor* ((Pursh) Maxim.), *Mahonia nervosa* ((Pursh) Nutt.), *Pinus monticola* (Dougl.), *Polystichum munitum* ((Kaulf.) Presl.), *Prunus emarginata* ((Dougl.) Walp.), *Pseudotsuga menziesii* ((Mirb.) Franco), *Pteridium aquilinum* ((L) Kuhn), *Rubus ursinus* (Cham. and Schlecht.), *Salix* spp., *Tsuga heterophylla* ((Raf.) Sarg.), *Thuja plicata* (Donn ex D. Don)

ecosystem type and climate, but were chosen to be representative of the range of conditions under which commercial salal is found in the local area.

Three 5 × 5 m plots were established at each of the six sites. The priority for plot establishment was consistency of overhead canopy and salal cover, and thus plots ranged from one to 10 m apart at each site. Sub-plots (0.5 × 0.5 m = 0.25 m^2) were located every 2 m along each plot boundary, for a total of eight sub-plots per plot (Fig. 3). The large plot size was used so that the commercial harvest of salal within them would be as representative of operational conditions as possible. Visual judgements are made by harvesters regarding what constitutes acceptable quality material. Harvesters therefore only remove a proportion of current growth, and that proportion was unknown at the outset of the study. The eight smaller sub-plots were thus established for clipping all current growth, which would be difficult to achieve in the larger plots because of the potentially large biomass of salal that this would constitute.

Treatment applications and measurements

Prior to budbreak in the spring (late May 1999), one 5 × 5 m plot on each site was commercially harvested (Commercial Harvest treatment) with the aid of a local experienced salal harvester. The intensity of picking was consistent with a normal commercial harvest. Commercial salal comprised stems from 46 to 76 cm in length (=1 to 3 years of growth) with a minimum of four leaves per stem, and with all leaves and stems free from damage or infection. Commercial harvesting normally involves removing and discarding imperfect leaves and stems from the selected branches. However, all imperfect leaves and stems were retained so that the actual biomass removed from plants through harvesting could be determined. In a second plot on each site, all current stems and leaves in sub-plots were clipped for biomass determination, regardless of whether or not they were of commercial quality. This current growth constituted the Commercial Harvest Control treatment.

Prior to budbreak in the subsequent year (late May 2000), regrowth in the Commercial Harvest plots was determined by clipping all current growth in sub-plots (Commercial Harvest Regrowth). In the third plot on each site, which was as yet unharvested, current growth in all sub-plots was also clipped for determination of current annual above-ground growth of undisturbed salal (Commercial Harvest Regrowth Control). The use of regrowth control treatment plots in the second year of the study allowed for treatments to be compared to control plots within each year without needing to account for the confounding factor of year-to-year variation in growth because of differences in weather conditions between years. (See Fig. 3 for plot and sub-plot layout, and treatments, which were randomly assigned at each site.)

When sub-plots were clipped, a 0.5 × 0.5 m metal frame was used to mark the sub-plot boundary. All current stems and leaves that were directly within the metal frame were clipped and retained; stems extending beyond the boundary were clipped and discarded.

All biomass from commercially harvested plots and sub-plots was dried at 60°C for 48 h before weighing.

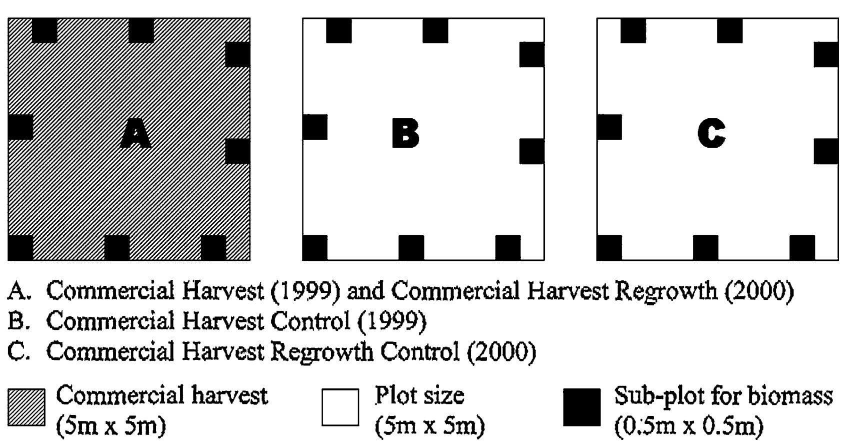

Fig. 3 Plot layout and treatments

In the second year (2000), lengths of current stems in each sub-plot were also measured, and stems placed in one of four stem length categories that reflect the commercial potential of stems: (i) ≤15.2 cm: no commercial value; (ii) 15.2–30.5 cm: commercial if pick 2–3 years' growth; (iii) 30.5–45.7 cm: commercial if pick 1–2 years' growth; and (iv) ≥45.7 cm: commercial if pick 1 year's growth, as in BC the short commercial stems of a single age (''tips'') are 46 to 61 cm. (The salal industry does not use metric measurements, and the four classes correspond to 6″, 6–12″, 12–18″ and >18″.)

Data analysis

The comparison of biomass between Commercial Harvest and Commercial Harvest Control treatments was based on different areas harvested (25 m^2 vs. 2 m^2, respectively), and therefore all data were converted to standard area-based units (g m^{-2}) before statistical analyses were carried out. For all data analyses, a single (mean) value was used for each plot and hence n=6. First, the Shapiro–Wilk test was used to confirm that assumptions of normality were valid for all comparisons, and data transformations were therefore not required. Paired t-tests (SPSS 10.0 for Macintosh) were then used to compare biomass between treatment and control plots in each year, and to compare the number of stems in each stem length category and overall at the end of the second year.

Results

Biomass removals (Fig. 4) in the Commercial Harvest treatment (131 g m^{-2}) were not significantly different (P = 0.86) from current above-ground growth in the undisturbed control treatment (135 g m^{-2}). The biomass of regrowth (Fig. 4) in the Commercial Harvest treatment in the subsequent year (144 g m^{-2}) was significantly greater (P = 0.036) than that of new growth in the comparable undisturbed control treatment (111 g m^{-2}). Likewise, the total number of new stems (Fig. 5) in the Commercial Harvest treatment in the subsequent year (60 stems m^{-2}) was significantly greater (P = 0.021) than the number in the undisturbed control treatment (50 stems m^{-2}). However, the number of stems in the four different stem length categories (Fig. 5) did not differ between the two treatments (P > 0.05).

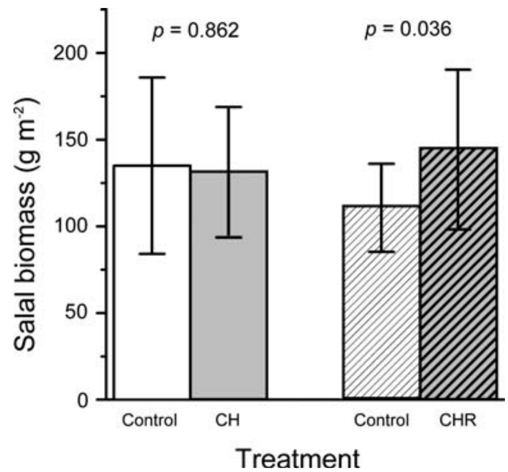

Fig. 4 Comparison of mean (±SD) annual above-ground biomass increment (g m^{-2}) of undisturbed salal (Control; clear bar) with biomass removed through commercial harvesting (CH; shaded bar) and undisturbed salal (Control; clear bar with cross-hatching) with regrowth 1 year after commercial harvesting (CHR; shaded bar with cross-hatching)

Discussion

As light availability is a better predictor of salal presence and abundance than other site characteristics

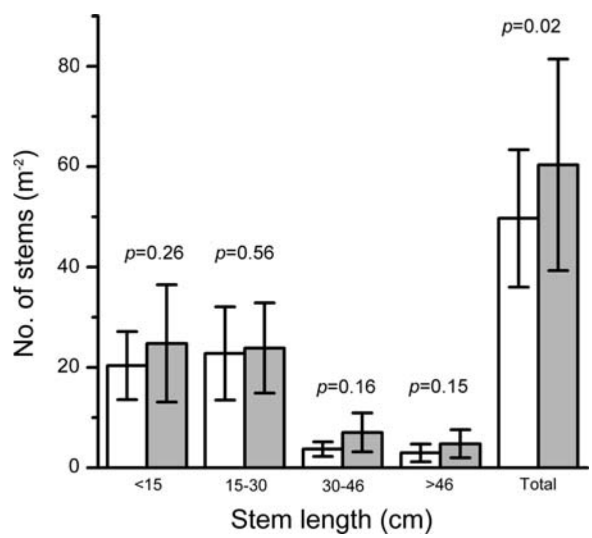

Fig. 5 Mean (±SD) current stem number (m^{-2}) of undisturbed salal (Control; clear bar) and of regrowth 1 year after commercial harvesting (Commercial Harvest Regrowth; shaded bar), by commercial stem length categories

(Vales 1986), the validity of comparisons between the small number of relevant studies is largely dependent on similarities in canopy cover, as well as ecosystem type. Nonetheless, there is a wide variation in annual above-ground biomass increment and total above-ground biomass in salal between previous studies, even though most have been carried out in the Pacific Northwest within partially shaded Douglas-fir forests. For example, the annual biomass increment of current stems and leaves that we found (110 to 135 g m^{-2}) is almost twice that found by Sabhasri (1961), although less than the total biomass of all leaves (224 g m^{-2}) found on salal growing in an open young cedar-hemlock stand (Bennett et al. 2003). This is much less than total above-ground biomass, which can range from 381 g m^{-2} (Messier and Mitchell 1994) to 1288 g m^{-2} (Sabhasri 1961).

The above ecological studies did not include commercial salal considerations in their objectives. However, the biomass of commercially-harvested salal is also highly variable. We found that 131 g m^{-2} was harvested in our study, although this includes all of the foliage and stems, some of which would be picked and then stripped by commercial harvesters. By comparison, in the only other known commercial salal study to date, Fredrickson (2000) found that commercial harvesting removed only 7.2 g m^{-2} from her study site. She noted, however, that this was not sufficient to initiate commercial activity because of the effort required to earn a reasonable wage on such a low productivity site. She found anecdotal evidence that 16.5 g m^{-2} is considered a ''good'' site on Vancouver Island, while as little as 8.4–14.0 g m^{-2} is considered ''good'' in Washington. However, our values are consistent with the 112.4 g m^{-2} harvested in trials on northern Vancouver Island (B. Titus, unpublished data, 2003).

Overall, our results show that there was no significant difference between the annual increment of new above-ground biomass in salal and that which was removed through harvesting. As the floral industry requires specific stem and leaf qualities, not all of the stems on a plant are commercially harvestable. The removal of the current growth of all stems was therefore equivalent to the removal of fewer stems of up to 3 years in age through commercial harvesting.

However, the annual above-ground biomass increment in the first year after commercial harvesting increased compared to that in undisturbed salal. There was little difference in weight between stems from control plots (2.23 g $stem^{-1}$) and commercially harvested plots (2.39 g $stem^{-1}$), and so we attribute the increase in biomass increment largely to the significantly greater number of stems. This is not unexpected because harvesting should stimulate bud growth (Keigley and Frisina 1998) and therefore increase the number of new stems. We have also heard anecdotally from local commercial harvesters that good salal harvesting practices can lead to increased commercial productivity because of increased stem production.

While biomass comparisons provide an indication of the regeneration abilities of salal after commercial harvest, stem length comparisons provide an indication of future commercial harvest value. There was a trend towards an increased number of longer stems after commercial harvesting, but treatment differences were not significant.

However, we assume that any increase in single stems that meet the minimum commercial length (46 cm (18″) for ''tips'' in BC) would allow for more sustainable harvesting for the same amount of harvester effort per site, as only the current year's growth is removed. Shorter stems must of necessity be combined with older stems to meet commercial standards. When this happens, up to 3 years of growth can be removed in some stems every year. We presume that any reduction in the number of older stems that are harvested will contribute to a more unsustainable level of removal.

Conclusions and future directions

Based on this initial study, we conclude that (i) commercial salal harvesting from previously unharvested sites removes the equivalent of 1 year's above-ground biomass increment, (ii) commercial salal harvesting increases the annual above-ground biomass in the subsequent year, and (iii) there is an increase in the total number of stems in the year after commercial harvesting. However, most commercially-harvested salal, and all of the salal in areas of purported growth decline resulting from over-harvesting, are harvested heavily every year and sites are often visited a number of times per year. The accumulative effects of harvest, such as repeated stimulation of buds and depletion of

below-ground carbohydrates stored in roots and rhizomes, should be taken into account in future studies. The large amounts of carbohydrates allocated to salal rhizomes (Messier and Mitchell 1994) may be very important for the continuation of commercial salal availability, as they are required for the plant's survival and growth under low light conditions (Bunnell 1990; Smith 1991). There is anecdotal evidence of decreasing stem lengths of harvestable salal in BC and the US (Cocksedge 2001, 2003). It is possible that salal in heavily and continuously harvested areas may lack sufficient reserves for adequate regrowth, especially if photosynthetic capability is reduced through leaf removal beyond a point required to maintain carbohydrate reserves. Comparing carbohydrate reserves in non-harvested with heavily harvested areas, or above- and below-ground biomass ratios, might give a better indication of the long-term effects of harvesting.

While it is known that salal can share resources between plants arising from and connected by the same rhizomes (Bunnell 1990; Messier 1992) and that rhizomes can cover up to 29 m^2 (Huffman et al. 1994a), the extent to which sharing resources over large areas could decrease localized effects of harvesting is also unknown.

Regarding the statistical design of studies, the high variability that we encountered between plots on the same site and between sites suggests that: (i) harvested plots should be as large as possible, and (ii) as many replicates as can be feasibly incorporated into a study should be used.

Acknowledgements We wish to thank those in the floral and forest industry who helped us understand the intricacies of the salal industry, particularly Rick Ross, Bob Brown, Bob Geary, Sarawuth Heang, Cho Chung, Sharon Curtis, Eric Gagne and Mike Desrochers. We also wish to thank those who shared insights on our work (including, Nancy Turner, Patrick von Aderkas, Barbara Hawkins, Alan Thomson, Jim Simpson, John Smith, Graham Cocksedge, Darcy Mitchell, Sinclair Tedder, Ramsay Farran, Tim Brigham, Kelly Vodden, Jim Freed, Su Alexander and Heidi Ballard), those who shared resource access with us (including Arthur Robinson (NRCanada) for assistance with work on Rocky Point sites (Dept. of National Defence), and Gordon Joyce, Russ Floyd, and Peter Thompson for assistance with work on Capital Regional District Watershed sites), and two anonymous reviewers for their insightful comments on an earlier draft of this paper. This work was partially funded by a grant from Global Forest Foundation (GF-18-2000-82), and constitutes part of the M.Sc. thesis work of the senior author.

References

Bell A (1993) Plant form: An illustrated guide to flowering plant morphology. Oxford University Press Inc., New York, NY, 340 pp

Bennett JM, Blevins LL, Barker JE, Blevins DP, Prescott CE (2003) Increases in tree growth and nutrient supply still apparent 10 to 13 years following fertilization and vegetation control of salal-dominated cedar–hemlock stands on Vancouver Island. Can J For Res 33:1516–1524

Blatner KA, Schlosser WE (1997) The floral and Christmas greens industry of the Pacific Northwest. Project report to the U.S. Forest Service PNW Research Station, Portland, OR, 27 pp

Bunnell RL (1990) Reproduction of salal (*Gaultheria shallon*) under forest canopy. Can J For Res 20:91–100

Cline MG (1997) Concepts and terminology of apical dominance. Am J Bot 84:1064–1069

Cocksedge W (2001) The Role of co-operatives in the non-timber forest product industry: Exploring issues and options using the case study of salal (*Gaultheria shallon*; Ericaceae). BC Institute for Co-operative Studies, University of Victoria, Victoria, BC, Occasional Paper 2, 41 pp

Cocksedge W (2003) Social and ecological aspects of the commercial harvest of the floral greenery, salal (*Gaultheria shallon* Pursh; Ericaceae). MSc thesis, Dept. of Biology, University of Victoria, Victoria, BC, 127 pp

De Geus PMJ (1995) Botanical forest products in British Columbia: An overview. Integrated Resources Policy Branch BC Ministry of Forests, Victoria BC, 51 pp

Fraser L, Turkington R, Chanway CP (1993) The biology of Canadian weeds. 102. *Gaultheria shallon* Pursh. Can J Plant Sci 73:1233–1247

Fredrickson SH (2000) Non-timber forest products: A study of salal productivity, inventory of commercial plant and fungus species, and recommendations for management on the Nanaimo rifle range lands. MSc thesis, Royal Roads University, Victoria, BC, 61 pp

Green RN, Klinka K (1994) A field guide to site identification and interpretation for the Vancouver Forest Region. Research Branch, B.C. Ministry of Forests, Victoria BC, 285 pp

Haeussler S, Coates D (1986) Autecological characteristics of selected species that compete with conifers in British Columbia: A literature review. Information Services Branch, B.C. Ministry of Forests, Victoria BC, 180 pp

Huffman DW, Tappeiner JC, Zasada JC (1994a) Regeneration of salal (*Gaultheria shallon*) in the central Coast Range forests of Oregon. Can J Bot 72:39–51

Huffman DW, Zasada JC, Tappeiner JC (1994b) Growth and morphology of rhizome cuttings and seedlings of salal (*Gaultheria shallon*): Effects of four light intensities. Can J Bot 72:1702–1708

Jones ET, McLain RJ, Weigand J (2002) Nontimber forest products in the United States. University Press of Kansas, Lawrence KS, 424 pp

Keigley RB, Frisina MR (1998) Browse evaluation by analysis of growth form. volume I: Methods for evaluating condition and trend. Montana Fish Wildlife and Parks MT, 153 pp

Koch JM (1983) Salal plant structure, growth, and allometric relationships under several forest stand densities in south coastal British Columbia. BSc Forestry thesis, Faculty of Forestry, University of British Columbia. Vancouver, BC, 50 pp

Luttmerding HA, Demarchi DA, Lea EC, Meidinger DV, Vold T (1990) Describing ecosystems in the field. MOE manual 11. 2nd edn. BC Ministry of Environment Lands and Parks, Victoria BC, 213 pp

Messier C (1992) Effects of neutral shade and growing media on growth, biomass allocation, and competitive ability of *Gaultheria shallon*. Can J Bot 70:2271–2276

Messier C, Mitchell AK (1994) Effects of thinning in a 43-year-old Douglas-fir stand on above- and below-ground biomass allocation and leaf structure of understory *Gaultheria shallon*. For Ecol Manage 68:263–271

Nations JD (1992) Xateros, chicleros, and pimenteros: Harvesting renewable tropical forest resources in the Guaemalan Petén. Conservation of Neotropical Forests. Columbia University Press, New York, NY, pp. 208–219

Ross R (1998) The changing future of NTFPs. In: Carr M, Mitchell DA (eds) Proceedings from the non-timber forest products workshop, 3–5 April 1998, Alert Bay, BC. Inner Coast Natural Resource Centre Society, Alert Bay, BC, pp 15–16

Sabhasri S (1961) An ecological study of salal *Gaultheria shallon* Pursh. PhD thesis, University of Washington, WA, 134 pp

Smith NJ (1991) Sun and shade leaves: clues to how salal (*Gaultheria shallon*) responds to overstory stand density. Can J For Res 21:300–305

Vales DJ (1986) Functional relationships between salal understory and forest overstory. MSc thesis, Faculty of Forestry, University of British Columbia, Vancouver, BC, 164 pp

Wills RM, Lipsey RG (1999) An economic strategy to develop non-timber forest products and services in British Columbia. Final Report to Forest Renewal British Columbia, Grant No. PA97538-ORE, Victoria, BC, 117 pp